International Journal of Contemporary Dental and Medical Reviews (2014), Article ID 011014, 5 Pages

REVIEW ARTICLE

The relevance of physico-chemical and diagnostic properties of saliva during orthodontic treatment

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Received 01 October 2014;
Accepted 14 October 2014

doi: 10.15713/ins.ijcdmr.1

How to cite the article:
Sushma Dhiman, Aditi Gaur, Sandhya Maheshwari, Saba Khan, "The relevance of physico-chemical and diagnostic properties of saliva during orthodontic treatment," Int J Contemp Dent Med Rev, vol. 2014, Article ID 011014, 2014.
doi: 10.15713/ins.ijcdmr.1

Abstract

Saliva is the principal defensive mechanism in the oral cavity and is critical for preserving and maintaining the health of oral tissues. The physico-chemical properties of saliva are affected by the local factors in the oral cavity and general health of an individual. Orthodontic treatment significantly affects the chemical composition and physical nature of oral fluids. The alteration in the properties of saliva can be utilized to evaluate the advent of orthodontics treatment in an individual. The present article focuses on the relevance of the physic-chemical properties of saliva during the progression of orthodontic treatment and the significance of saliva as a diagnostic analyte during orthodontic treatment.

Keywords: Contamination, orthodontic bonding, physico-chemical, saliva

Introduction

Saliva is the principal defensive mechanism in the oral cavity and is critical for preserving and maintaining the health of oral tissues. The composition and physical properties of saliva are subject to changes by the local and systemic conditions of an individual. Patients who undergo orthodontic therapy present with oral ecologic changes because of the retentive nature of the orthodontic appliances. These appliances create an ecological niche for bacterial activity leading to changes in the oral environment thus altering the salivary profile. The physico-chemical properties of saliva determine the progress of orthodontic treatment and its adverse effects in an orthodontic patient. Thus, continuous monitoring of the salivary composition, pH, flow rate and its chemical profile is desirable in orthodontic patients enabling the clinicians a better control over the orthodontic treatment. The present article summarizes the role of saliva during various stages of orthodontic treatment.

Orthodontic Bonding

The first step of orthodontic treatment in the oral cavity begins with bonding of the fixed orthodontic appliances on the dentition. Orthodontic appliances are bonded to the tooth surface using polymeric materials. Contamination by moisture, saliva or blood during bonding procedures leads to a reduced bond strength of orthodontic brackets.[1] Non-contaminated enamel surfaces have the highest bond strengths but saliva contamination leads to lower shear bond strengths for metallic brackets.[2] Mehmet *et al.* studied the effect on shear bond strength of four adhesives after salivary contamination and found a reduction in the bond strength values of most of the adhesives.[3] Prasad *et al.* in their study evaluated the effect of salivary and blood contamination on bond strengths of conventional and self-etching bonding systems. They suggested that the contamination during the bonding procedure reduced the shear bond strength of all groups.[4] Mao *et al.* demonstrated the effect of salivary contamination at various steps of bonding procedure and concluded that salivary contamination both before and after the application of the primer could significantly reduce the shear bond strength of orthodontic brackets.[5] Paschos *et al.* used artificial saliva in their study and showed contamination by saliva significantly decreased the bond strength when using the conventional acid-etching method.[6]

Detailed investigations of the effect of saliva on the alteration of polymeric material properties has not been broadly covered

in the dental materials literature but it has been suggested that the presence of high mucous protein content and enzymes in saliva would result in increased degradation reactions in the adhesive. Water sorption by the adhesive matrix leads to plasticizing of the polymer and a notable reduction of its mechanical properties and physical characteristics.[7] It can also cause hydrolytic breakdown of the filler surface through either elemental leaching from the filler surface or destruction of the filler-matrix bonding.[8]

Thus, orthodontic bonding procedure requires complete isolation to prevent the contamination of the tooth surface leading to adequate bond strength of the orthodontic adhesives. Further, newer materials like moisture insensitive and hydrophilic adhesives have been developed to aid in orthodontic bonding in cases where salivary contamination is difficult to control.[9] Deprá *et al.* concluded in their study that saliva contamination reduced bond strength when a conventional hydrophobic resin composite was used. However, the hydrophilic resin was not affected by the contamination.[10]

Few authors have suggested that use of self-etching primers could lead to improved bonding in cases where moisture control is difficult.[11-14] In situations in which moisture contamination is critical there is a distinct advantage in using hydrophilic primers.[15] Cyanoacrylates have been tested in various studies and have shown better performance under conditions where there was a salivary contamination. Although shear bond strength of cyanoacrylate adhesive has been found to be significantly lower than other adhesives, but it is the only adhesive that is not affected by contamination.[16] Hence, cyanoacrylate adhesive is indicated under moist conditions (particularly the saliva), and when a short setting time is required.[17]

Ciola *et al.* tested a moisture insensitive primer on wet enamel and showed that it had higher bond strength outcomes compared to one-step etching primer.[18] Silverman *et al.* suggested the use of a light cured glass ionomer which exhibited sufficient tensile strength in the presence of salivary contamination.[19] Few researchers have also suggested the role of protective liquid polish in preventing the effect of contamination by blood or saliva.[20]

Remineralization of White Spot Lesions

The enamel decalcification is one of the most common and undesirable complications of the orthodontic therapy[21] Lee *et al.* demonstrated the formation of salivary pellicles on the surface of various orthodontic materials indicating their significance in the formation of bacterial adhesions during orthodontic treatment.[22] Bacterial growth promoted by the orthodontic appliances leads to decalcification of the mineralized tooth surfaces.[23] Demineralization of the enamel around brackets can be an extremely rapid process, which appears most frequently on the cervical and middle thirds of the buccal surfaces of the maxillary lateral incisors, mandible canines and the first premolars.[24] Saliva acts as a reparative medium against the demineralizing activity during orthodontic treatment. The reparative properties of saliva toward early demineralizing erosions have been shown *in vitro* studies.[25,26] Saliva acts as a remineralizing medium due to its protective properties such as salivary clearance, buffering power and its chemical composition.

Salivary Flow

Continuous salivary flow

It is the quantity of saliva which is produced at rest, without any exogenous or pharmacological stimulation. It is the basal unstimulated secretion which occurs as film that covers, moisturizes, and lubricates the oral tissues.

Stimulated saliva

Stimulated saliva as name suggests is produced by mechanical, gustatory, olfactory, or pharmacological stimulus and contributes to 80-90% of daily salivary production. In adults, normal total stimulated salivary flow ranges from 1 to 3 mL/min and the normal unstimulated salivary flow ranges from 0.25 to 0.35 mL/min. Enhanced remineralization of white spot lesions by stimulated salivary flow (e.g., from chewing a sugar-free gum) illustrates dynamic protective effects of saliva.[8] Salivary flow can be used as a clinical marker, which can be used to evaluate the oral health of orthodontic patients.

Salivary pH

Salivary pH is a measurement of acidity or alkalinity of the saliva. Normal pH of saliva is 6.3, but could be modified by an oral health. Decrease in salivary pH increases the susceptibility towards enamel demineralization. The pH at which enamel demineralization begins is the critical pH. Orthodontic appliances favor retention of food debris, decreasing salivary pH, thus increasing the microbial action. The oral health of orthodontic patients can be evaluated by assessing the pH of saliva using pH strips.

Increase in salivary pH after placement of orthodontic appliances indicates the anti-demineralization properties of saliva.[9] Carillo *et al.* evaluated various clinical markers along with salivary pH in 34 orthodontic patients and showed an increase in salivary pH highlighting the increase in host response on change in oral environmental conditions[27] Peros *et al.* conducted a study to determine the physiologic changes of salivary flow rate, pH, and buffer capacity and the levels of *Streptococcus mutans* and *Lactobacillus* spp. in patients undergoing fixed orthodontic treatment. They found a significant increase in stimulated salivary flow rate and salivary pH. They suggested that the 6-12th week of orthodontic therapy is the period of the most intensive intraoral growth of *S. mutans* and *Lactobacillus* spp.[28]

Although contradictory results were shown by Bonnetti *et al.* who showed that the placement of fixed orthodontic appliances

did not change the salivary pH, buffer capacity and flow rate after 1 year of treatment, most of the studies have shown a favorable change in the properties of saliva promoting remineralisation of decalcification lesions.[29]

Cleansing Action and Buffer Capacity

Saliva helps in mechanical cleansing of the residues like bacteria and debris in the oral cavity. Buffer capacity is the saliva ability to neutralize acids saliva buffers the acidic environment of the oral cavity thus preventing the growth of micro-organisms. Buffer capacity of the saliva can be measured by using reactive strips and thus indicating the host response toward acidic oral environment. An increase in buffer capacity of saliva was seen in orthodontic patients by Chang *et al.*[9]

Salivary Composition

Salivary fluid is an exocrine secretion which comprises of approximately 99% water, electrolytes (sodium, potassium, calcium, chloride, magnesium, bicarbonate, phosphate), glucose, nitrogenous products and proteins, which include enzymes, immunoglobulins, antimicrobial factors, mucosal glycoproteins, and traces of albumin.[11] The dissolution and deposition of minerals of the hydroxyapatite in enamel are regulated by various structural components of saliva. These include the inorganic, i.e., calcium and phosphate levels and fluoride content. The organic factors include proline-rich proteins (PRPs), statherins, cystatins and histatins.

Many components in saliva are taken up by dental biofilm and protect the enamel surface. The ability of the biofilm to sequester calcium, phosphate and fluoride from the saliva, as well as from sources outside the oral cavity allows enamel to undergo remineralization after demineralization.

Calcium and Phosphate Ions

Calcium availability remains the singular limiting factor in enamel remineralisation. While phosphate levels in resting saliva do not vary markedly, large fluctuations in calcium concentrations occur in an individual.[12]

Differences in calcium concentration have important implications for the critical pH and for the possibility of remineralization, since the latter will not occur when the degree of saturation of saliva with respect to tooth mineral is low. Remineralization may be enhanced by providing low levels of bio-available calcium and phosphate ions.[13]

Fluoride Ions

Fluoride adsorbs to the surface of the partially demineralized crystals and attracts calcium ions. Fluoride speeds up the growth of the new surface by bringing calcium and phosphate ions together and is also preferentially incorporated into the remineralized surface.[14] This produces a surface that is more acid resistant. A continuous supply of fluoride ions decreases the caries susceptibility of the enamel which can be made available by various fluoride releasing solutions, varnishes and toothpaste.[15-17]

Salivary Proteins

Salivary proteins include PRPs, statherins, cystatins and histatins. The acidic PRPs bind to hydroxyapatite, bind calcium ions, and inhibit crystal growth of calcium phosphate in supersaturated solutions.[18] When adsorbed onto the hydroxyapatite, the acidic PRPs are capable of binding numerous oral bacteria, which might reduce the acidic action of bacteria on enamel. Statherins and histatins also bind with high selectivity to hydroxyapatite[19] and inhibit crystal growth of calcium phosphate salts. *In vitro* studies on human enamel have shown that Histatin-1 enhances the rate of remineralisation when compared to statherin.[20] Thus, organic components of saliva also play a significant role in enamel remineralisation.

Role in Sliding Mechanics

Various *in vitro* studies have been conducted to evaluate the effect of dry and wet states on friction between orthodontic brackets and arch wires. When human saliva and dry testing were compared, the human saliva sometimes behaved as an adhesive (e.g., steel-on-steel couples) but at other times behaved as a lubricant (e.g., beta titanium archwires on stainless steel brackets). Ho *et al.* evaluated the frictional values when different archwires were pulled a distance of 2 mm through ceramic and stainless steel brackets. They concluded that lubrication in the form of saliva reduced friction.[30] Stannard *et al.* evaluated the effect of dry state and artificial saliva on the frictional properties of different archwires and suggested that artificial saliva did not increase friction for cobalt chromium, stainless steel sliding against stainless steel, or stainless steel wire on Teflon compared to the dry condition.[31] Leal *et al.* conducted a study evaluating the effect of dry state, human saliva and artificial saliva medium and concluded that dry states and water leads to increased friction when compared to friction values present in salivary media.[32]

Downing *et al.* showed an increase in friction between stainless steel and ceramic brackets when used with various archwire materials in the presence of artificial saliva. In most of the literature, it was confirmed that human saliva substantially facilitates sliding of wire-bracket couple beyond the dry state. Thus, the presence of saliva in the oral cavity reduces friction at the wire bracket interface in the orthodontic appliances.[21]

Use as a Diagnostic Analyte

Whole saliva is most often studied because its collection is easy, non-invasive and rapid to obtain without the need for

specialized equipment. Saliva can be used as a diagnostic medium to detect the biomarkers of orthodontic tooth movement. The underlying mechanism for tooth movement is an inflammatory process in the periodontal tissues which is mediated by biochemical molecules. These molecules can be detected in saliva and can be used to assess the progress of orthodontic treatment. Inflammatory cytokines such as RANKL/OPG ratio, interleukin (IL)-8, granulocyte-macrophage-colony-stimulating factor, IL-1β and tumor necrosis factor-alpha have been detected in the saliva of orthodontic patients.[22-24] Increase in the levels of molecules like salivary IgA have also been linked to root resorption in orthodontic patients.[25] Chair-side diagnostic kits are being developed to analyze these biomarkers and thus to provide the clinicians an opportunity to monitor and manipulate the progress of orthodontic treatment.

Salivary samples can also be used to assess the metal ions that leach out from orthodontic appliances. In orthodontics, a lot of emphases has been laid on release of nickel and chromium ions because of the hazardous nature of these elements. Several studies have been conducted to detect nickel ions levels in saliva in patients undergoing orthodontic treatment, although, no significant differences have been found in the salivary levels of metals in orthodontic patients and normal population.[26]

Senkutvan *et al.* evaluated the release of Ni and Ti from four types of archwires stored in artificial saliva. They found large variation in concentration of Ni released but the amount of Ni ions released in all test solutions diminished with time and was below the critical value necessary to induce allergy and below daily dietary intake level.[33] Milošev *et al.* used artificial saliva medium to evaluate the effect of fluoride ions on the dissolution of metals from archwires.[34] Briceño *et al.* determined the effect of different phases of NiTi wires on their corrosion in artificial saliva and concluded that martensitic phase improved the corrosion resistance of these wires.[35] Amini *et al.* conducted a study to evaluate the effect of stress on salivary metal ions levels from archwires. They suggested that the induction of stress led to increasing in nickel ions concentration and gradual increase in chromium ion concentration.[36] Zhang *et al.* tested the biocompatibility of composite archwire in artificial saliva solutions simulating oral environment thus suggesting a new biomaterial for application as orthodontic material.[37] Zhang *et al.* studied the corrosion behavior of composite archwires in the presence of protein in artificial saliva and suggested that low protein content led to increased corrosion of wires. Brandão *et al.* evaluated the corrosion of metal brackets due to brushing with dentifrices. Artificial salivary medium was used for evaluation, and they concluded that immersion in artificial saliva did not affect alter the surface corrosion of these brackets.[38] Huang *et al.* showed that diamond like coating of archwires had lesser wear using artificial saliva.[39] Knutson *et al.* evaluated the corrosion of temporary anchorage devices in artificial saliva and effect of fluoride on their corrosion. They showed that presence of fluoride in saliva increased carrion of temporary anchorage devices.[40]

Conclusion

It is important for the clinicians to have knowledge of the role of saliva and the changes in its physic-chemical properties during orthodontic treatment. This would enable the orthodontists in monitoring the progress of orthodontic treatment and control its adverse effects like enamel demineralization from the initial stages. Further research in this field will also help the orthodontists in managing patients suffering from systemic conditions featuring xerostomia. Newer chair-side diagnostic kits and lab-on-chip technologies need to be developed so that real-time monitoring of salivary samples can be done in orthodontic patients.

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